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The Position of Software in the Work Breakdown Structure (WBS) for Space Systems

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14. ABSTRACT

This report addresses the issue of where software should reside in the Work Breakdown Structure (WBS) for a space system. The report describes the various software activities that must be performed for space system development and provides recommendations as to where these activities belong in the standard product-oriented space system WBS structure, with specific focus on the very important cross-product software activities that must be accomplished on complex, software-intensive space systems. The report also recommends a specific organizational structure with responsibility for these cross-product software activities.

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Contents

Tables

Acronym List

AFOTEC	Air Force Operational Test and Evaluation Center
ATE	Automated Test Equipment
CAIG	Cost Analysis Improvement Group
CDR	Critical Design Review
CMMI®	Capability Maturity Model® Integration℠
COTS	Commercial Off the Shelf
DOD	Department of Defense
FCA	Functional Configuration Audit
HDBK	Handbook
IMS	Integrated Master Schedule
IOT&E	Initial Operational Test and Evaluation
IPPD	Integrated Product and Process Development
IPT	Integrated Product Team
MIL	Military
NSS	National Security Space
OSD	Office of the Secretary of Defense
PCA	Physical Configuration Audit
PDR	Preliminary Design Review
PM	Program Management
SDP	Software Development Plan
SDR	System Design Review
SEIT	Systems Engineering, Integration and Test
SLOC	Source Lines of Code
SM	Service Mark
SRR	System Requirements Review
TPM	Technical Performance Measure
TRR	Test Requirements Review
U.S.	United States
USECAF	Undersecretary of the Air Force
WBS	Work Breakdown Structure

Executive Summary

This report was prepared to address the issue of where software should reside in the Work Breakdown Structure (WBS) for a space system. The report first provides some background on Integrated Product and Process Development (IPPD) and the standard product-oriented WBS structure established for space systems by MIL-HDBK-881A [DOD1]. The report then describes the various software activities that must be performed for space system development and provides recommendations as to where these activities belong in this standard product-oriented space system WBS structure. While development activities for individual software items (e.g., software requirements definition, design, implementation, and test) will reside at lower WBS levels beneath the WBS elements for the products in which the software items reside, there are a large number of very important cross-product software activities that must be accomplished on our complex, software-intensive space systems. This report strongly recommends that these activities belong in WBS Software Common Elements at Level 2 and below. The cross-product activities of the Level 2 WBS Software Common Element, in particular, are critically important for program success, and the report provides an enumeration of these activities. The report also includes discussions of (1) the relationship between the Software and Systems Engineering, Integration and Test WBS common elements; (2) software WBS elements for the early acquisition phases; and (3) the relationship between WBS elements and organizational structures. The report concludes by recommending that the critically important activities of the Level 2 WBS Software Common Element be performed by a Level 2 Software Systems Engineering, Integration and Test Integrated Product Team (IPT) specifically established for that purpose.

1. Background

This report addresses the question of where software should appear in the Work Breakdown Structure (WBS) for a space system. This question was raised by several different programs in the early stages of space system acquisitions. In particular, the question that was asked was whether or not software should be placed at Level 2 in the WBS for a space system.

The correct answer to where software should go in a space system WBS is more complicated than a single number. The Work Breakdown Structure provides a mechanism for enumerating the work being performed on a program, both for the contractor team and for the government program office. Software, in fact, belongs at a number of places in the WBS, some higher than others. This is due to the diversity of the software tasks that must be performed as well as to the position of software in the space system product structure. The following sections describe the recommended positioning of the various software tasks in a space system WBS and provide rationale for their location.

2. Integrated Product and Process Development (IPPD) versus Functional Organizational WBS Structures

In the early 1990s, the Air Force changed from using a functional organization for program management to using Integrated Product and Process Development (IPPD). Under the earlier functional organizational structure, managers were responsible for a particular function, such as systems engineering, hardware development, software development, integration and test, or logistics support. Under the new IPPD paradigm, however, programs are organized by product into Integrated Product Teams (IPTs), and the manager of each IPT is responsible for developing that IPT's product to meet its allocated requirements within its allocated cost and schedule. All aspects of the product development are intended to be integrated in this management structure, including product-level systems engineering; hardware and software development; specialty engineering; integration and test; and verification/qualification. In addition, product development includes developing the processes and any associated hardware and software needed for the development, verification/qualification, manufacturing, deployment, operations, support, training, and disposal of the product. The IPT product development manager is responsible for all costs associated with all of these aspects of the product.

From a WBS perspective, in a functional organizational structure, Level 2 of the WBS would match the designated functions. Thus, there were Level 2 entries in the WBS that contained all work for each function, so all aspects of software development were placed under a single Level 2 WBS element. With the transition to IPPD, Level 2 of the WBS structure became product oriented rather than function oriented.

3. The Product-Oriented Standard Space System WBS

For many years the Department of Defense has had a handbook for defining the WBS for acquisitions. A new version of this handbook has recently been published (MIL-HDBK-881A, "Work Breakdown Structures for Defense Materiel Items," 30 July 2005 [DOD1]). This handbook is mandatory for all programs that fall under DoD 5000.2 [DOD2]. National Security Space Acquisition Policy NSS 03-01 [USECAF], however, also requires the use of this handbook for defining the WBS structure for all National Security Space (NSS) programs subject to NSS 03-01. In paragraph AP3.4, NSS 03-01 states: "Generally, the NSS program office shall follow the standard product-oriented WBS structure specified in MIL-HDBK-881." The WBS structure is required to be documented in the program's Cost and Software Reporting Plan, which must be approved by the chairman of the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG). Thus, any deviation from the standard product-oriented WBS structure must be approved at the OSD level for NSS programs subject to NSS 03-01.

The standard product-oriented WBS structure for space systems is found in Appendix F of MIL-HDBK-881A and provided in the Appendix of this report. The first two levels of this WBS structure are summarized in Table 1.

The table in the Appendix has been enhanced to illustrate where space and ground operational and other supporting software products would reside in this standard space system WBS structure.[1] As shown in the table in the Appendix, the software development activities reside in multiple Level 4 WBS elements within the product in which the software resides. Each of these software WBS elements at Level 4 includes all of the work involved in developing that particular software item [i.e., software requirements definition, software architectural design, software detailed design, software implementation and unit testing, software unit integration and testing, software qualification testing, software specialty engineering (e.g., information assurance, safety, human systems integration, reliability/maintainability/availability)], plus all of the associated software project management activities (e.g., planning, tracking and controlling; configuration management; joint management reviews) and quality enhancement activities (e.g., peer reviews, product evaluations, joint technical reviews) for that software item.

Table 1. Levels 1 and 2 of the Standard Product-Oriented WBS Structure for Space Systems

Level 1	Level 2
Space System	
	SEIT/PM[2] and Other Common Elements
	Space Vehicle (1....n as required)
	Ground (1...n as required)
	Launch Vehicle

1 Other supporting software includes software used in satisfying, verifying, or validating requirements or used in performing or supporting operations or maintenance. Examples include simulators, training software, testbed software, and automated test software.

2 SEIT = Systems Engineering, Integration and Test; PM = Program Management.

The "Common Elements" in the standard product-oriented WBS structure, however, are extremely important. MIL-HDBK-881A states the following (paragraph F.3.1, p. 76):

> "Common WBS Elements must include, as a minimum, systems engineering, integration and test, and program management (SEIT/PM). Common elements are found throughout all levels of a WBS and are located one WBS level below the product oriented WBS they support (e.g., structures and mechanisms SEIT/PM would be captured at Level 5 below the Structures and Mechanisms Subsystem). Other common elements, such as training or data, as applicable, may be included here. *The table above* [i.e., the table in Appendix F of MIL-HDBK-881A] *is not complete without the application of common elements.*" [emphasis in *italics* added]

The need for Software Common Elements in the standard product-oriented space system WBS is described in the following section.

4. Software Common Element Activities

In addition to the software development activities described above for the space, ground, and supporting software products, there are a large number of important software activities that transcend the software product boundaries. These "cross-product" activities belong under the category of "Common Elements" shown in Table 1 at Level 2 and in the table in the Appendix at Levels 2, 3, and 4.

There are always important software activities that apply across all of the software products on the program. This report strongly recommends that these activities be included in a Level 2 WBS Common Element for software. An appropriate name for this Software Common Element is "Software Systems Engineering, Integration and Test." Examples of the important activities included in this Level 2 WBS Software Common Element are as follows:

- Software Planning, Tracking and Control
  - Conducting a cross-program Software Integrated Product Team (IPT) to engage all software product organizations in the work of the Software Common Element
  - Preparing and maintaining an integrated Software Development Plan (SDP) for all software development and maintenance activities across the program
  - Providing software engineering management and control to enforce adherence to the SDP and other compliance documents
  - Conducting Capability Maturity Model® Integration℠ (CMMI®) process maturity appraisals and working with the software product organizations to improve their processes[3]
  - Defining, collecting, analyzing and reporting uniform software metrics across the program, and ensuring corrective action is taken where indicated by the metrics
  - Participating in joint management meetings (e.g., monthly Program Management Reviews, monthly software management reviews)
  - Identifying and resolving cross-product software issues
  - Identifying software-related risks and interfacing with the program risk management process for risk handling and mitigation
  - Developing and maintaining integrated software schedules as part of the Integrated Master Schedule (IMS), including software build schedules

3 Capability Maturity Model and CMMI are registered in the U.S. Patent and Trademark Office by Carnegie Mellon University. Capability Maturity Model Integration is a Service Mark (SM) of Carnegie Mellon University.

- Participating with the software product teams to define the software build contents (requirements, capabilities) to ensure integration and delivery needs are met across the program
- Implementing an integrated closed-loop corrective action process across the software products
- Implementing and maintaining a uniform software deficiency/change reporting system across the software products
- Analyzing software deficiency reports across the software products to identify systemic problems and root causes and to initiate corrective actions
- Apprising program management of the status of the software development effort across the program; elevating issues that cannot be resolved by the Software IPT to program management for resolution

- Software-Related Systems Engineering, Integration and Test
  - Leading the specification of software-related requirements for the system and segments
  - Participating in the allocation of requirements from system to segment to element/subsystem to software item, including the allocation of software specialty engineering requirements (e.g., safety, information assurance, reliability/maintainability/availability, human system integration)
  - Participating in the space and ground segment level designs, including space/ground and hardware/software trades
  - Leading the development of the overall (cross-product) processing hardware and software architecture
  - Participating in the definition of external and inter-segment interfaces and the resolution of external and inter-segment interface issues involving software
  - Leading the definition of software-to-software and software-to-hardware interfaces within and among the space and ground elements/subsystems and software and hardware items, and resolving related interface issues
  - Evaluating software requirements and software architectures developed for the software items by the software product teams to ensure that the software level requirements properly implement their allocated higher level requirements and that the individual software architectures are consistent with the overall processing hardware and software architecture
  - Leading the identification and resolution of margin issues for computer resource utilization
  - Defining, collecting, analyzing and reporting uniform software-related Technical Performance Measures (TPMs) across the program, and taking corrective action where indicated by the TPMs
  - Participating in integration testing of hardware and software items, subsystems/elements, segments and the system, including identifying and documenting software-related deficiencies

- Participating in subsystem/element, segment and system qualification testing, including evaluating software-related requirements verification status and documenting software-related deficiencies
- Monitoring software build integration testing of the software products, including participating in software deficiency identification and documentation
- Monitoring software qualification testing of the software products, including participating in evaluating software-related requirements verification status and documenting deficiencies
- Ensuring that all software items meet their allocated software specialty engineering requirements and that all cross-product software specialty engineering requirements are met (e.g., integrated fault detection and isolation; human systems integration; information assurance)
- Implementing, populating, validating and maintaining the operational databases (e.g., flight constants database, ground operational databases) and related software required to support integration, verification, launch preparation and operations
- Providing software-related support to operational testing (e.g., Initial Operational Test and Evaluation (IOT&E) by the Air Force Operational Test and Evaluation Center (AFOTEC))
- Providing software-related support to launch preparation and operations

- Software-Related Technical Reviews and Audits
  - Participating in system, segment and element/subsystem level requirements reviews, design reviews and test readiness reviews for software-related topics [e.g., System Requirements Review (SRR), System Design Review (SDR), Preliminary Design Review (PDR), Critical Design Review (CDR), Test Readiness Review (TRR)]
  - Attending and evaluating software level joint technical reviews and meetings (e.g., software PDRs, CDRs and TRRs; build architecture, design and test readiness reviews) held by the software product organizations
  - Participating in peer reviews of development products held by the software product organizations
  - Performing software product evaluations of development products and working with the software product organizations to resolve quality issues
- Software Configuration Management
  - Implementing and maintaining a uniform software configuration management system across the software products
  - Participating on program and software Configuration Control Boards to evaluate impacts of software-related changes
  - Performing periodic software configuration audits across the program

- Conducting software Functional Configuration Audits (FCAs) and Physical Configuration Audits (PCAs)

- Software Quality Assurance
  - Performing software quality audits of software processes and products across the program, and issuing non-compliance reports
  - Monitoring software qualification testing for the software products
  - Maintaining software quality assurance records
  - Communicating quality issues to program and software management
  - Implementing a closed-loop process for tracking and resolving non-compliance issues, including elevating those issues when necessary

Table 2 contains the first two levels of the product-oriented standard space system WBS with some of the typical Level 2 Common Elements for space systems elaborated and showing the recommended position of the Level 2 Software Systems Engineering, Integration, and Testing Common Element. The table in the Appendix also shows these common elements at Level 2.

Cross-product activities are also possible for subsets of the software products. Hence, it is possible for Software Common Elements to exist at Levels 3 and below in the WBS (see Appendix). As an example, a Ground Software Common Element ("Ground Software Systems Engineering, Integration and Test") may exist at Level 3 under the Ground Segment to handle software activities that cross ground software product boundaries. This would be needed, for example, when the ground segment has multiple software items, possibly being developed by multiple subcontractors, that must be integrated together to perform the ground segment functions and meet the ground segment requirements. These lower level Software Common Elements include activities such as those listed above for the Level 2 Software Common Element, but only as these activities apply to the products within their parent WBS element (e.g., the Ground Software Common Element would handle only cross-ground

Table 2 Space System WBS with Level 2 Common Elements Elaborated

Level 1	Level 2
Space System	
	Program Management (PM)
	Systems Engineering, Integration and Test (SEIT)
	Software Systems Engineering, Integration and Test
	Training
	Operational Site Activation and Operations Support
	Common and Peculiar Support Equipment
	Initial Spares and Repair Parts
	Data
	Other Common Elements, as required
	Space Vehicle (1....n as required)
	Ground (1...n as required)
	Launch Vehicle

software product activities). Even if lower level Software Common Elements exist in the WBS, the Level 2 Software Common Element is still necessary to handle software activities that cross software product boundaries for the entire program.

5. Relationship Between the SEIT and Software Common Elements

In many existing space system WBSs, the software cross-product activities are placed at Level 3 under the Level 2 SEIT WBS element. While this reduces the number of Level 2 WBS Common Elements, it is not optimal for new software-intensive space systems.

Older legacy space systems were hardware centric, with ground-based data processing and little onboard software. Newer space systems have become information centric, with all missions being dependant upon large amounts of complex software, both onboard the space vehicle [10^5 to 10^6 Source Lines of Code (SLOC)] and on the ground (10^6 to 10^7 SLOC). In addition, software development has become acknowledged as one of the highest risk areas in these new software-intensive space systems. The position of the Software Common Element in the WBS must be commensurate with the risk and importance of software in the space system. In addition, the position of the Software Common Element must ensure that a budget is allocated to the critically important software cross-product activities that is sufficient to ensure proper execution of those activities.

The manager responsible for the Software Common Element must be experienced in software project management and software systems engineering, integration, and test within the context of large complex software-intensive systems. The manager responsible for the SEIT WBS element, however, usually has a hardware systems engineering background with no direct software experience or expertise. Placing the software cross-product activities beneath the SEIT WBS has historically resulted in decreased visibility for software, inappropriate allocation of resources to software, and incorrect evaluation of the importance of software issues and risks until those issues and risks have become major problems. Additionally, placing the software cross-product activities beneath the SEIT WBS has resulted in many of these critically important activities not being performed because the responsible management was not sufficiently knowledgeable to be able to define the activities needing to be accomplished or lacked the experience and expertise necessary to understand the importance of these activities. As a result, frequently the software cross-product activities performed under SEIT management are limited to chairing a software process working group and preparing the Software Development Plan.

For the above reasons and from a software risk management perspective, the optimal position for the program-level Software Systems Engineering, Integration, and Test WBS Common Element is at Level 2 in the space system WBS structure, at the same level as the program-level SEIT WBS Common Element. The program-level Software Systems Engineering, Integration, and Test WBS Common Element should not be subordinate to the program-level SEIT WBS Common Element. Similarly, Software Common Elements at lower WBS levels should not be subordinate to the lower level SEIT WBS Common Elements, but should be at the same level as their corresponding lower level SEIT WBS Common Elements.

6. Software WBS Elements for the Early Acquisition Phases

The standard space system WBS structure in MIL-HDBK-881A is designed for the System Acquisition portion of the acquisition life cycle since it elaborates the product hierarchy down through Level 4. Per NSS 03-01, the System Acquisition portion of the acquisition life cycle includes Phase B (Preliminary Design), Phase C (Detailed Design), and the development portion of Phase D (Build and Operations).

In the Pre-System Acquisition portion of the acquisition life cycle, the products are not yet being developed, and a full elaboration of the WBS structure for the eventual product hierarchy is not yet needed. The Pre-System Acquisition portion of the acquisition life cycle includes Pre-Phase A (Concept Studies) and Phase A (Concept Development) per NSS 03-01. During the Pre-System Acquisition portion of the acquisition life cycle, critical decisions about system requirements and architecture are made, and risk reduction efforts are undertaken. It is imperative that software be a full partner with hardware in these critical decisions and risk reduction efforts for new software-intensive space systems. It is also imperative that software systems engineering and risk reduction be allocated its own budget, separate from the SEIT, space segment, and ground segment budgets.

During Pre-Phase A, the software work will focus on software systems engineering activities (e.g., software architecture trade studies), downstream software risk reduction activities (e.g., prototype mission processing or mission planning algorithm development), and software development planning, tracking, and controlling for software-related activities performed during this phase. Therefore, at the beginning of Pre-Phase A, the principal software element in the space system WBS should be the Level 2 Software Common Element "Software Systems Engineering, Integration, and Test." However, software development may begin in certain areas, such as the end-to-end system simulator and prototype software for high-risk areas. So even in Pre-Phase A, there may be some software product development activities that require lower level software product development WBS elements.

During Phase A, most software work will still be performed under the Level 2 Software Common Element. Examples of important cross-product software activities performed during this phase are the system/segment requirements definition for software-related requirements, system design decisions related to software, development of the top-level processing hardware and software architecture, software process definition and software development planning for the entire program, and software trade studies [e.g., use of Commercial Off-the-Shelf (COTS) and reuse software]. As the program moves into and through Phase A, more activities will be performed by the segments, and the WBS will need to be elaborated to lower levels to reflect the evolving product structure. Work may also be performed under Software Common Elements at WBS Level 3 and possibly at Level 4. In addition, work will begin to be performed under lower level software product development WBS elements for more software items, especially those software items considered mission critical or having higher risk.

Thus, the Software Common Element at WBS Level 2 is important throughout all acquisition phases. In the beginning, software activities are principally performed under this WBS element. As the program progresses through Pre-System Acquisition and into System Acquisition, software activities are also performed under additional lower level WBS software common elements and software product development elements.

7. Relationship Between WBS Elements and Organizational Structures

The WBS is, by definition, a hierarchical structure used for enumerating and organizing all of the work on a program, principally for the purpose of managing program costs. When using IPPD as a management philosophy, the program is organized into a hierarchical structure of IPTs, with each IPT being responsible for all aspects of the development of its assigned product. Typically, the manager of an IPT is responsible for all work performed under a particular WBS element and all of its subordinate elements (e.g., the ground segment IPT manager is responsible for all work performed under the Level 2 Ground Segment WBS element, including all of its subordinate elements). In this way, the costs for all of the work under a particular IPT can be rolled up into a single WBS element, making overall cost management for that IPT easier.

For IPPD, the product-development WBS elements and the IPTs are usually in one-to-one correspondence, down to the lowest level in the IPT structure. In addition, there should also be an IPT responsible for each of the WBS Common Elements (with some exceptions, such as the Level 2 WBS element associated with the cost of data preparation and delivery). Thus, at Level 2, there should be a Systems Engineering, Integration, and Test IPT that is responsible for the work under the Level 2 WBS SEIT Common Element. Similarly, there should be a Level 2 IPT for Software Systems Engineering, Integration, and Test that is responsible for the work under the Level 2 WBS Software Common Element. The recommendation for separate Level 2 IPTs for the SEIT and Software WBS Common Elements should not be interpreted to mean that one IPT considers only hardware and the other only software. The Systems Engineering, Integration, and Test IPT must be software cognizant, and the Software Systems Engineering, Integration, and Test IPT must be hardware cognizant. In addition, these two IPTs must work closely together. There is precedence for having a Level 2 IPT responsible for the activities under the Level 2 WBS Software Common Element (described in Section 4 above). During Pre-Phase A, the Space Radar program established a Software Directorate (3-letter organization) that successfully carried out this responsibility.

Shortly after IPPD was instituted, the need for integrative mechanisms was recognized in order to facilitate cross-IPT integration and to coordinate cross-IPT actions. Traditional examples of integrative mechanisms are Interface Control Working Groups (ICWGs), Engineering Review Boards (ERBs), and Test Planning Working Groups (TPWGs). Most commonly, responsibility for managing these traditional integrative mechanisms has been allocated to the Level 2 SEIT IPT, with the activities associated with managing these integrative mechanisms included under the Level 2 WBS SEIT Common Element. While the Level 2 SEIT IPT has systems engineering products for which it is responsible, much of the work of the SEIT IPT consists of managing integrative mechanisms across the space system's product development IPTs and other lower level SEIT IPTs.

Similarly, while the Level 2 Software Systems Engineering, Integration, and Test IPT has software products for which it is responsible, much of the work of this IPT consists of managing integrative mechanisms across the space system's software product organizations and other lower level Software Systems Engineering, Integration, and Test IPTs. Integrative mechanisms must also exist between

the SEIT IPTs and Software Systems Engineering, Integration, and Test IPTs, both within and between levels of the IPT structure.

Many problems on space programs can be attributed to inadequate communication across multiple IPTs involving numerous organizations, sometimes with wide geographical dispersion. Research in the effective application of IPPD has resulted in a number of papers concerning effective integrative mechanisms.[4] Further study needs to be done to define the most effective integrative mechanisms for both software and systems engineering in the space system domain. Such a study is out of the scope of this report.

4 See, for example, Tyson R. Browning, "Multi-Team Integration: Interdependence and Integrative Mechanisms," Proceedings of the Sixth Annual International Symposium of INCOSE, Boston, 7-11 July 1996, pp. 787-794.

8. Conclusion

This report has described the various software activities that must be performed for space system development and has provided recommendations as to where these activities belong in the Standard Product-Oriented WBS structure for space systems. Development activities for individual software items will reside at lower WBS levels underneath the WBS elements for the products in which the software items reside. There are, however, a large number of very important cross-product software activities that must be accomplished. These activities belong in WBS Software Common Elements at Level 2 and below. In particular, the cross-product activities of the Level 2 WBS Software Common Element are especially important for program success, and should be the responsibility of a Software Systems Engineering, Integration, and Test Level 2 IPT.

References

[DOD1] Department of Defense, Work Breakdown Structures for Defense Materiel Items, Department of Defense Handbook, MIL-HDBK-881A, 30 July 2005.

[DOD2] Department of Defense, *Operation of the Defense Acquisition System*, Department of Defense Instruction (DoDI) 5000.2, 12 May 2003.

[USECAF] Undersecretary of the Air Force, *National Security Space Acquisition Policy*, Number 03-01, 27 December 2004.

Appendix—Recommended Product-Oriented WBS for Software-Intensive Space Systems

The Table 1A has been taken from MIL-HDBK-881A (Table F, P. 76). Some elements in Table F from MIL-HDBK-881A have been modified, and others have been added to illustrate a more complete WBS structure for today's software-intensive space systems. These modified and added elements are shown in *italics* in Table 1A.

Table 1A. Recommended Product-Oriented WBS for Space System

Level 1	Level 2	Level 3	Level 4
Space System			
	Program Management Systems Engineering, Integration and Test (SEIT)		
		End-to-End System Simulator[5]	
			SEIT/PM and Other Common Elements[6]
			End-to-End Simulator Hardware
			End-to-End Simulator Software
	Software Systems Engineering, Integration and Test		
		Software Planning, Tracking and Controlling[7]	
		Software-Related Systems Engineering, Integration and Test[7]	
		Software-Related Technical Reviews and Audits[7]	
		Software Configuration Management[7]	
		Software Quality Assurance[7]	
	Training		
		Training Subsystem	
			SEIT/PM and Other Common Elements[6]
			Training Subsystem Hardware
			Training Subsystem Software
		Training Services and Courseware	
	Operational Site Activation and Operations Support		
	Common and Peculiar Support Equipment		
		Peculiar Support Equipment (1...n)	
			SEIT/PM and Other Common

5 Generally, the End-to-End System Simulator is included under the SEIT Level 2 WBS.

6 Each SEIT/PM and Other Common Elements WBS entry at levels 3 and 4 in this table must be expanded into a list of common elements appropriate to the higher level WBS element to which it is subordinate. See the Level 2 WBS Common Elements as examples.

7 These are examples of possible Level 3 WBS elements for the Level 2 Software Common Element "Software Systems Engineering, Integration and Test. See Section 4 of this report for an example elaboration of the activities that would be included under each of these Level 3 WBS elements.

Level 1	Level 2	Level 3	Level 4
			Elements[6] *Peculiar Support Equipment Hardware (1..n)* *Peculiar Support Equipment Software (1…n)*
	Initial Spares and Repair Parts Data *Other Common Elements, as required* Space Vehicle (1….n as required)		
		SEIT/PM and Other Common Elements[6] *Software Systems Engineering, Integration and Test*	
		Spacecraft Bus	
			SEIT/PM and Other Common Elements[6] Structures and Mechanisms Subsystem Thermal Control Subsystem Electrical Power Subsystem Attitude Control Subsystem Propulsion Subsystem Telemetry, Tracking, and Command Subsystem Spacecraft Bus Flight Software
		Spacecraft Simulator	*Spacecraft Simulator Hardware* *Spacecraft Simulator Software*
		Spacecraft Flight Testbed	*Spacecraft Flight Testbed Hardware* *Spacecraft Flight Testbed Software*
		Spacecraft Automated Test Equipment (ATE)	*Spacecraft ATE Hardware* *Spacecraft ATE Software*
		Communication / Payload	
			SEIT/PM and Other Common Elements[6] Communication (1…n as required) Payload (1…n as required) Communication/Payload Flight Software (1…n as required)
		Comm/Payload (1...n) Simulator	*Comm/Payload (1...n) Simulator Hardware* *Comm/Payload (1...n) Simulator Software*
		Comm/Payload (1...n) Flight Testbed	*Comm/Payload (1...n) Flight Testbed Hardware* *Comm/Payload (1...n) Flight Testbed Software*
		Comm/Payload (1...n) ATE	*Comm/Payload (1...n) ATE Hardware* *Comm/Payload (1...n) ATE Software*
		Booster Adapter	

Level 1	Level 2	Level 3	Level 4
	Ground (1…n as required)	Space Vehicle Storage Launch Systems Integration Launch Operations & Mission Support	
		SEIT/PM and Other Common Elements[6] *Software Systems Engineering, Integration and Test*	
		Ground Terminal Subsystems	
			SEIT/PM and Other Common Elements[6] *Ground Terminal Hardware* *Ground Terminal Software*
		Command and Control Subsystem	
			SEIT/PM and Other Common Elements[6] *Command and Control Subsystem Hardware* *Command and Control Subsystem Software*
		Mission Management Subsystem	
			SEIT/PM and Other Common Elements[6] *Mission Management Subsystem Hardware* *Mission Management Subsystem Software*
		Data Archive/Storage Subsystem	
			SEIT/PM and Other Common Elements[6] *Data Archive/Storage Subsystem Hardware* *Data Archive/Storage Subsystem Software*
		Mission Data Processing Subsystem	
			SEIT/PM and Other Common Elements[6] *Mission Data Processing Subsystem Hardware* *Mission Data Processing Subsystem Software*
		Mission Data Analysis and Dissemination Subsystem	
			SEIT/PM and Other Common Elements[6] *Mission Data Analysis and Dissemination Subsystem Hardware* *Mission Data Analysis and Dissemination Subsystem Software*
		Mission Infrastructure Subsystem	
			SEIT/PM and Other Common Elements[6] *Mission Infrastructure Subsystem Hardware* *Mission Infrastructure Subsystem Software*
		Collection Management	

Level 1	Level 2	Level 3	Level 4
		Collection Management Subsystem	
			SEIT/PM and Other Common Elements[6]
			Collection Management Subsystem Hardware
			Collection Management Subsystem Software
		Ground Simulators (1…n)	
			SEIT/PM and Other Common Elements[6]
			Ground Simulator Hardware (1..n)
			Ground Simulator Software (1…n)
	Launch Vehicle		

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